PJM Guidance for NERC MOD-026-027
Generation Owner Preparation & Submittal

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For Public

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Contents

Introduction

The purpose of this document is to provide guidance to Generator Owners (GOs) on PJM's dynamic model verification requirements. These requirements meet or exceed those required under NERC Standards MOD-026 and MOD-027.
In NERC standards MOD-026 and MOD-027, Transmission Provider (TP) shall provide GO instructions on obtaining the following:

1. The acceptable model list: PJM complies with NERC, and provides web link access to NERC acceptable mode list.
2. The model block diagram and/or data sheet, or model data of the current models: PJM provides the current (in-use) models and technical reference document, as applicable.

In Addition, PJM provides some information to assist GO preparation and submittal.
NERC MOD-026/027-R1 is available in the appendix A-1.

Section I – Acceptable Model List

The dynamic model, both of excitation control system model and governor model, must be in the PJM Acceptable Models List in appendix-2. The PJM acceptable model list includes input from the historical NERC Acceptable Models List, other TPs acceptable model list, and PJM experience.

While not exhaustive, the dynamic model must, comply with the below rules:

- For individual synchronous machines, the generator excitation control system includes the generator, exciter, voltage regulator, impedance compensation and power system stabilizer.
- For an aggregate generating plant, the Volt/Var control system includes the voltage regulator & reactive power control system controlling and coordinating plant voltage and associated reactive capable resources.
- Turbine/governor and load control applies to conventional synchronous generation.
- Active power/frequency control applies to aggregate inverter based generators.
- Momentary cessation is mandatory for inverter-based resources.
- For Battery Energy Storage System (BESS), Renewable Energy Plant Controller (REPC) for plant level control is optional, instead of mandatory.

User-defined models are not acceptable. PJM requires submittal of generic models with appropriate due diligence made to closely match unit performance.

If after developing generic models, a GO has technical concerns about the generic model's performance, GO shall provide PJM the technical documents[1] demonstrating the concern. The documents shall consist and contain the following:

1) GO shall provide PJM the technical document to demonstrate the in-adequacy of currently available generic model. The demonstration shall consist of comparison to the real response acquired via lab or field test, which allows for comparison of the UDM and generic model performance;

2) GO shall provide PJM UDMs for two commercial software platforms: PTI PSS/e and PowerTech PSAT. According NERC MOD-026-1 R2.1.4 and NERC MOD-027-1 R2.1.4 GO must provide PJM the model structure, data, control closed loop. Black box is not accepted;

3) GO shall provide PJM a minimum of one generic model; and

[1] 1) The GO must permit PJM to discuss the evidence documents with third parties, such as but not limited a test labs, consultants, or research institutes.

4) GO shall provide PJM the UDM DLL, which is workable with PJM's current software versions for PTI PSS/e and PowerTech PSAT. If PJM updates its version of either software, GO shall provide updated UDM DLL within 30 days on receiving notice from PJM.

PJM will make the final decision whether a currently available generic model cannot adequately represent the unit response.

Some exceptions to this exist such as HVDC circuits and FACTs devices.

The dynamic model list from some plants are listed in the appendix A-3 as for the reference.

Special requirement of Momentary Cessation is in the appendix A-4.

Section II – The model block diagram and data sheet

GO, or contracted third party, shall verify Generator Excitation Control System or Plant Volt/Var Control Functions according NERC MOD-026-R2.

GO, or contracted third party, shall verify the Turbine/Governor and Load Control or Active Power/Frequency Control Functions according to NERC MOD-027-R2.

In the appendix A-5, there are some technical documents listed as the reference. Industry standards and technical methods to acquire dynamic model are available in these documents, which contain technical information on system block functionality, modeling, and testing.

When generic model is used, GO can opt to provide the model block diagram, because the generic model block diagram and data sheet is available in PSS/e user manual. When the UDM is used, the detail model block diagram and data sheet must be provided in the technical report.

Section III – current in-use model

PJM provides GO the current in-use dynamic model, which consists of *.dyr, *.raw, and *.lis.
The dyr file is a dynamic data file, describing the component dynamic behavior when the power system is undergoing the transient status.
The raw file is a collection of unprocessed data that specifies a Bus/Branch network model for the establishment of a power flow working case.
The lis file is not a native PSSE file format. This file contains the output of the dynamics DOCU function, which reports on dynamic models found in the network. The lis file is provided to assist user understanding of the model.
Both of raw file and dyr are required when GO submit the MOD-026/027 case. The lis file is not required when GO submit MOD-026/027 case.

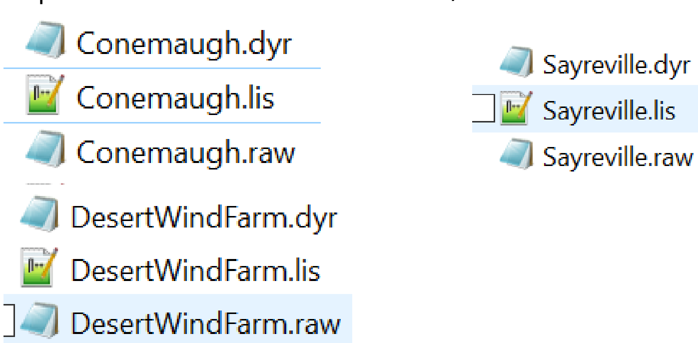

Figure 1 Example of current in-use model

Section IV – Submittal

GO shall submit the MOD-026/027 case via PJM Planning Community website: https://pjm.force.com/planning/s/.

1. User Guide and Interface

The user guide for PJM Planning Community is available:
https://www.pjm.com/-/media/committees-groups/community-user-guide.ashx.

The video tutorial for PJM Planning Community is available:
https://www.screencast.com/t/Ndhzq9Yt4

The below figure is the interface for the MOD-026-027 submittal:

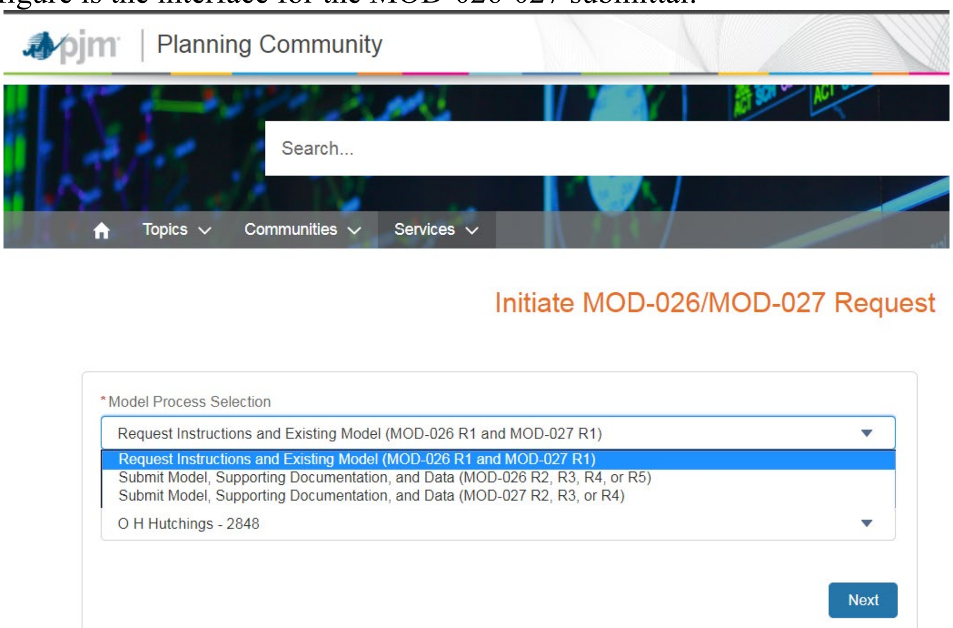

Figure 2 User Interface of PJM Planning Community

2. Documents Requirement

Within the case, the GO shall attach all related documents. The documents shall consist of:

- The laboratory test report. The test report shall be produced and certified by the tester. The signature must be full name. and
- The load flow model *.raw file. and
- The dynamic model *.dyr file. or
- Other related documents or explanation if needed.
- The Single Line Diagram (*.sld) is recommended to be included also.

The additional information on system model and dynamic model is listed in Appendix A-6 as the reference.

3. Case Number

After submittal, Planning Community will assign a case with a tracking ID, case number, for each submittal. The case will be processed within 90 calendar days.

4. Submittal Attachment Check List

The submittal must include three essential files:

1) Load flow file *.raw in PSS/e Ver 35. The *.raw file shall contain all transmission elements within the local power system and network topology until POI bus, include but not limit: machine, load, bus, branch, transformer, and et al. SLD in PSS/e format is welcomed, but not mandatory. For renewable plant, the aggregated model is required.
2) The example of power flow model is in Fig.8 and Fig.9.
3) Dynamic model file *.dyr in PSS/e Ver 35. The *.dyr file shall contain the dynamic model of the generation system for dynamic analysis. For convention generation units, the *.dyr file shall include but not limit: generator model, exciter model, governor model, stabilizer PSS model, compensator model, over exciter limiter model, under exciter limit model, and load control model. For renewable units, the *.dyr file shall contain the dynamic model of the renewable generation system for dynamic analysis, include but not limited to: renewable generator model, renewable electrical control model, renewable drive train model (if applicable), renewable pitch control model (if applicable), renewable aerodynamic model (if applicable), renewable torque control model (if applicable), renewable plant control model, renewable voltage relay model (if applicable), renewable frequency relay model (if applicable).
4) The example of dynamic model file *.dyr format is in Fig.10 and Fig.11.
5) Laboratory test report. The report is very important to help PJM judge whether the model accurately represent the generation control system. The report shall contain the equipment manufacturer information, laboratory test procedure and result, and dynamic model. The comparison between the lab test plots and software simulation curves is welcomed.
    a. Machine MVA base is essential to MOD-026.
    b. Machine identification must coincide with EIA-860 sheet. https://www.eia.gov/electricity/data/eia860/
    c. The report shall be written in the technical document format, and signed with the full name of the document preparer and reviewer.
    d. The dynamic model shall be expressed according to PSS/e format, as below examples in Fig.3, Fig.12, and Fig.13.

Salient Pole Synchronous Generator Model
PSS/E Model GENTPJU1

Description	Parameter	Value	Units	CON
d-axis OC transient time constant	T'do (>0)	5.7	s	J
d-axis OC sub-transient time constant	T"do (>0)	0.0088	s	J+1
q-axis OC transient time constant	T'qo	0	s	J+2
q-axis OC sub-transient time constant	T"qo (>0)	0.06	s	J+3
Inertia	H	2.518	MW.s/MVA	J+4
Damping	D	0	pu	J+5
d-axis synchronous reactance	Xd	1.4	pu	J+6
q-axis synchronous reactance	Xq	0.873	pu	J+7
d-axis transient reactance	X'd	0.335	pu	J+8
q-axis transient reactance	X'q	0.873	pu	J+9
d-subtransient reactance	X"d	0.25	pu	J+10
q-subtransient reactance	X"q	0.25	pu	J+11
leakage reactance	Xl	0.11	pu	J+12
saturation factor at 1.0 pu Et	S(1.0)	0.1	pu	J+13
saturation factor at 1.2 pu Et	S(1.2)	0.275	pu	J+14
current saturation factor	Kis	0		J+15

Figure 3 Tabular expression for dynamic model in PSS/e format

Section V – GO self-review

It is optional instead of mandatory for GO to have a self-evaluation test before submitting the model. The system model performance to be checked is shown in the below table.

Table 1 check list for GO self-review

	Test	Action	Conventional Generator	Renewable (Wind Machine, Solar PV, BESS)	Result check
1	No fault	Initial transient simulation, then 6 cycles	√	√	Power, P & Q shall be flat, no change Power Angle shall be flat, no change Voltage, Etrm & EFD, shall be flat, no change
2	disturbance	Apply LLL fault at POI bus for 5 cycles, Then trip and run simulation 20 seconds	√	√	Power, angle, and voltage shall settle down quickly after the short period oscillation. For most plant, the oscillation period should be less than 3 seconds.
3	Voltage step Reference	Utilize PSS/e command BAT_INCREMENT_VREF to test Exciter response, Incremental of Gref ±0.03pu	√	√	Etrm reponse shall match the lab test result. Pmech shall keep to be stable
4	Open Circuit	Utilize PSS/e command BAT_ESTR_OPEN_CIRCUIT_TEST to test the excitation open circuit response	√		EFD and ETRM shall stable flat after a few seconds
5	Response Ratio	Utilize PSS/e command BAT_ESTR_RESPONSE_RATIO_TEST to test Exciter response ratio, power factor set to be 0.85	√		EFD shall quickly (within 1second) rise to 4-12pu then stable flat.
6	Governor step reference (Gref)	Utilize PSS/e command BAT_INCREMENT_GREF to test Governor response, Incremental of Gref ±0.005pu	√		Speed and mechanical power shall be stable after the change.
	Governor response (Grun)	Utilize PSS/e command BAT_GSTR to initialize and Test the governor response, initial load is set to 0.8pu with 0.1 loading step, Run to 120 seconds	√		Pmech keep flat Speed change to the set value then stable
7	Voltage ride through (Vrt)	Apply LLL fault at POI bus for 9 cycles, Then trip and run simulation 60 seconds		√	After fault cleared, all output shall be stable.
8	Frequency reference	Incremental of frequency ±0.005pu with PSS/e command: BAT_CHANGE_WNMOD_VAR,**,'1','REPCA1',3, -0.005		√	Frequency change to the set value then stable
9	LVRT	Check Low voltage ride through in the simulation log file		√	The protection relay breaker shouldn't open and trip the branch.

Section VI – PJM's review

PJM will identify the models as either usable or not useable per the standard. If the model is useable, it will be forwarded to other PJM teams to do security check. After passing the security check, PJM will update the system model. If the model is not useable, the initial case will be closed with the reasons for determining the case not useable. The final evaluation result, either "usable" or "not usable," will be posted on the PJM Planning Community where the original case submitted.

Section VII – Responding to a not useable finding

If not usable, the GO shall follow NERC MOD-026/027-R3 requirement within 90 days and create a new case in Planning Community to correct or update the dynamic files associated with a not useable finding. A new case is required because the initial case was closed as not useable and cannot be reopened. As with an initial submittal, within the new case, the GO shall attach all related documents. The documents shall consist of the laboratory test report, dyr file, raw file, and any other documents. The response shall include an explanation of the updated information.

NERC MOD-026/027-R3 is in Appendix A-7.

Appendix

A-1 NERC MOD-026/027-Requirement 1

A-1.1, NERC MOD-026-R1

R1. Each Transmission Planner shall provide the following requested information to the Generator Owner within 90 calendar days of receiving a written request : *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

- Instructions on how to obtain the list of excitation control system or plant volt/var control function models that are acceptable to the Transmission Planner for use in dynamic simulation,
- Instructions on how to obtain the dynamic excitation control system or plant volt/var control function model library block diagrams and/or data sheets for models that are acceptable to the Transmission Planner, or
- Model data for any of the Generator Owner's existing applicable unit specific excitation control system or plant volt/var control function contained in the Transmission Planner's dynamic database from the current (in-use) models, including generator MVA base.

Figure 4 MOD-026 Requirement 1

A-1.1, NERC MOD-027-R1

R1. Each Transmission Planner shall provide the following requested information to the Generator Owner within 90 calendar days of receiving a written request: *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

- Instructions on how to obtain the list of turbine/governor and load control or active power/frequency control system models that are acceptable to the Transmission Planner for use in dynamic simulation,
- Instructions on how to obtain the dynamic turbine/governor and load control or active power/frequency control function model library block diagrams and/or data sheets for models that are acceptable to the Transmission Planner, or
- Model data for any of the Generator Owner's existing applicable unit specific turbine/governor and load control or active power/frequency control system contained in the Transmission Planner's dynamic database from the current (in-use) models.

Figure 5 MOD-027 Requirement 1

A-2 PJM Acceptable Model List

Model Type	Model Description	PSS/e Model Name	Status
Machine Model	Round Rotor Generator Model (IEEE Std 1110 §5.3.2 Model 2.2)	GENROU	Not Recommended
	Salient Pole Generator Model (IEEE Std 1110 §5.3.1 Model 2.1)	GENSAL	Not Accepted
	Round Rotor Generator Model (IEEE Std 1110 §5.3.2 Model 2.2)	GENROE	Not Recommended
	Salient Pole Generator Model (IEEE Std 1110 §5.3.1 Model 2.1)	GENSAE	Not Recommended
	Round Rotor Generator with DC Offset Torque Component	GENDCO	Acceptable
	Generator Type J	GENTPJ1	Acceptable
	WECC Generator model	GENQECU	Acceptable
	Classical Generator Model (IEEE Std 1110 §5.4.2)	GENCLS	Not Accepted
	Third Order Generator Model	CGEN1	Not Recommended
	Transient Level Generator Model	GENTRA	Not Accepted
	Salient Pole Frequency Changer Model	FRECHG	Acceptable
	"Two-cage" or "One-Cage" Induction Generator	CIMTR1, CIMTR3	Acceptable
Excitation System Models	IEEE Std 421.5 Type AC1A	ESAC1A	Acceptable
	IEEE Std 421.5 Type AC1C	AC1C	Acceptable
	Modified IEEE Std 421.5 Type AC1A	ESURRY	Acceptable
	IEEE Std 421.5 Type AC2A	ESAC2A	Acceptable
	IEEE Std 421.5 Type AC2C	AC2C	Acceptable
	IEEE Std 421.5 Type AC3A	ESAC3A	Acceptable
	IEEE Std 421.5 Type AC3C	AC3C	Acceptable
	IEEE Std 421.5 Type AC4A	ESAC4A	Acceptable
	IEEE Std 421.5 Type AC4C	AC4C	Acceptable
	IEEE Std 421.5 Type AC5A	ESAC5A	Acceptable
	IEEE Std 421.5 Type AC5C	AC5C	Acceptable
	IEEE Std 421.5 Type AC6A	ESAC6A	Not Accepted
	IEEE Std 421.5 Type AC6A Modified IEEE Std 421.5 Type AC6A (added speed multiplier)	AC6A	Acceptable
	IEEE Std 421.5 Type AC6C	AC6C	Acceptable
	IEEE Std 421.5 Type AC7B IEEE AC7B Excitation System Model w/ OEL for Brushless Exciters and GE EX2100 Controls	AC7B	Acceptable
	IEEE Std 421.5 Type AC7C	AC7CU1	Acceptable
	IEEE Std 421.5 Type AC8B	AC8B	Acceptable
	Modified IEEE Std 421.5 Type AC8B	ESAC8B	Acceptable
	IEEE Std 421.5 Type AC8C	AC8CU1	Acceptable
	IEEE Std 421.5 Type AC9C	AC9CU1	Acceptable
	IEEE Std 421.5 Type AC10C	AC10C	Not Accepted*
	IEEE Std 421.5 Type AC11C	AC11CU1	Acceptable

* The model is not available in PSS/e Ver 34.9 and newer version.

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Excitation System Models	IEEE Std 421.5 Type DC1A	ESDC1A	Acceptable
	IEEE Std 421.5 Type DC1C	DC1C	Acceptable
	IEEE Std 421.5 Type DC2A	ESDC2A	Acceptable
	IEEE Std 421.5 Type DC2C	DC2C	Acceptable
	IEEE Std 421.5 Type DC3A	DC3A	Acceptable
	IEEE Std 421.5 Type DC4B	DC4B	Acceptable
	IEEE Std 421.5 Type DC4C	DC4CU1	Acceptable
	IEEE Std 421.5 Type ST1A	ESST1A	Acceptable
	IEEE Std 421.5 Type ST1C	ST1C	Acceptable
	IEEE Std 421.5 Type ST2A	ESST2A	Acceptable
	IEEE Std 421.5 Type ST2C	ST2C	Not Accepted*
	IEEE Std 421.5 Type ST3A	ESST3A	Acceptable
	IEEE Std 421.5 Type ST3C	ST3C	Not Accepted*
	IEEE Std 421.5 Type ST4B Modified IEEE Std 421.5 Type ST4B (without OEL & UEL inputs and Vgmax)	ESST4B	Acceptable
	IEEE Std 421.5 Type ST4C	ST4CU1	Acceptable
	IEEE Std 421.5 Type ST5B**	ST5B	Acceptable
	IEEE Proposed Type ST5B Excitation System	URST5T	Acceptable
	IEEE Std 421.5 Type ST5C	ST5C	Acceptable
	IEEE Std 421.5 Type ST6B	ST6B	Acceptable
	IEEE Std 421.5 Type ST6C	ST6CU1	Acceptable
	IEEE Std 421.5 Type ST7B	ST7B	Acceptable
	IEEE Std 421.5 Type ST7C	ST7C	Acceptable
	IEEE Std 421.5 Type ST8C	ST8CU1	Acceptable
	IEEE Std 421.5 Type ST9C	ST9CU1	Acceptable
	IEEE Std 421.5 Type ST10C	ST10CU1	Acceptable
	1968 IEEE Type 1+B127	IEEET1	Acceptable
	Modified 1968 IEEE Type 1	IEET1A	Acceptable
	Modified 1968 IEEE Type 1	IEET1B	Acceptable
	1968 IEEE Type 2	IEEET2	Acceptable
	1968 IEEE Type 3	IEEET3	Acceptable
	1968 IEEE Type 4	IEEET4	Acceptable
	Modified 1968 IEEE Type 4	IEEET5	Acceptable
	Modified 1968 IEEE Type 4	IEET5A	Acceptable
	1981 IEEE Type AC1	EXAC1	Acceptable
	Modified 1981 IEEE Type AC1 Modified 1981 IEEE Type AC1 (modified rate feedback source and with added speed multiplier)	EXAC1A	Acceptable
	1981 IEEE Type AC2	EXAC2	Acceptable
	1981 IEEE Type AC3	EXAC3	Acceptable
	Modified 1981 IEEE Type AC3	ESAC3A	Not Accepted*

* The model is not available in PSS/e Ver 34.9 and newer version.

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Excitation System Models	1981 IEEE Type AC4	EXAC4	Acceptable
	1981 IEEE Type DC1	IEEEX1	Acceptable
	Modified 1981 IEEE Type DC1	IEEEX2	Acceptable
	Modified 1981 IEEE Type DC1	IEEX2A	Acceptable
	1981 IEEE Type DC2	EXDC2	Acceptable
	Modified 1981 IEEE Type DC2	IEEEX2	Acceptable
	1981 IEEE Type DC3	IEEEX4	Acceptable
	1981 IEEE Type ST1	EXST1	Acceptable
	1981 IEEE Type ST2	EXST2	Acceptable
	Modified 1981 IEEE Type ST2	EXST2A	Acceptable
	Modified 1981 IEEE Type ST2	IEEEX3	Acceptable
	1981 IEEE Type ST3	EXST3	Acceptable
	Modified 1981 IEEE Type ST3	ESST3A	Acceptable
	General Purpose Rotating Excitation System Model	REXSYS	Acceptable
	General Purpose Rotating Excitation System Model	REXSY1	Acceptable
	Proportional/Integral Excitation System Model	EXPIC1	Acceptable
	Bus or Solid Fed SCR Bridge Excitation System Model	SCRX	Acceptable
	Bus or Solid Fed SCR Bridge Excitation System Model Type NEBB (NVE)	EXNEBB	Acceptable
	Bus or Solid Fed SCR Bridge Excitation System Model Type NI (NVE)	EXNI	Acceptable
	Simplified Excitation System	SEXS	Not Accepted
	IVO Excitation System Model	IVOEX	Acceptable
	ELIN Excitation System	CELIN	Acceptable
	Basler Static Voltage Regulator Feeding DC or AC Rotating Exciter	EXBAS	Acceptable
	Brown-Boveri Transformer-Fed Static Excitation System Model	BBSEX1	Acceptable
	Static PI Transformer Fed Excitation System	EXELI	Acceptable
	GE EX2000 Excitation System	EX2000	Not Accepted
	AEP Rockport excitation system	EMAC1T	Acceptable
	Czech Proportional/Integral Excitation System Model	BUDCZT	Acceptable
	High Dam Excitation System Model	URHIDT	Acceptable
Power System Stabilizer	Transient Excitation Boosting Stabilizer Model	BEPSST	Acceptable
	Dual-Input Signal Power System Stabilizer Model	IEE2ST	Acceptable
	1981 IEEE Power System Stabilizer	IEEEST	Acceptable
	IVO Stabilizer Model	IVOST	Acceptable
	Ontario Hydro Delta-Omega Power System Stabilizer	OSTB2T	Acceptable
	Ontario Hydro Delta-Omega Power System Stabilizer	OSTB5T	Acceptable
	IEEE Std 421.5-2005 Single-Input Stabilizer Model	PSS1A	Acceptable
	1992 IEEE Type Dual-Input Signal Stabilizer Model	PSS2A	Acceptable
	IEEE Std 421.5-2005 PSS2B Dual-Input Stabilizer Model	PSS2B	Acceptable

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Power System Stabilizer	IEEE Std 421.5-2016 PSS2C Dual-Input Stabilizer Model	PSS2CU1	Acceptable
	IEEE Std 421.5-2005 PSS3B Dual-Input Stabilizer Model	PSS3B	Acceptable
	IEEE Std 421.5-2016 PSS3C Dual-Input Stabilizer Model	PSS3C	Not Accepted*
	IEEE Std 421.5-2005 PSS4B Dual-Input Stabilizer Model	PSS4B	Acceptable
	IEEE Std 421.5-2016 PSS4C Dual-Input Stabilizer Model	PSS4C	Not Accepted*
	IEEE Std 421.5-2016 PSS5C Dual-Input Stabilizer Model	PSS5C	Not Accepted*
	IEEE Std 421.5-2016 PSS6C Dual-Input Stabilizer Model	PSS6CU1	Acceptable
	IEEE Std 421.5-2016 PSS7C Dual-Input Stabilizer Model	PSS7CU1	Acceptable
	PTI Microprocess-Based Stabilizer Model	PTIST1	Acceptable
	PTI Microprocess-Based Stabilizer Model	PTIST3	Acceptable
	Speed Sensitive Stabilizer Model	STAB1	Acceptable
	ASEA Power Sensitive Stabilizer Model	STAB2A	Acceptable
	Power Sensitive Stabilizer Model	STAB3	Acceptable
	Power Sensitive Stabilizer Model	STAB4	Acceptable
	Dual-Input Signal Power System Stabilizer Model	ST2CUT	Acceptable
	WECC Supplementary Signal for Static Var System	STBSVC	Acceptable
	Synchronous Condenser Auxiliary Control Model	SYNAXBU1	Acceptable
Current Compensation Models	Cross-Current Compensation Model with Reactive Current Feedback	CCOMP4U1	Acceptable
	Voltage Regulator Compensating Model	COMP	Acceptable
	Cross and Joint Current Compensation Model	COMPCC	Acceptable
	IEEE Std 421.5 Current Compensator	IEEEVC	Acceptable
	Remote Bus Voltage Signal Model	REMCMP	Acceptable
Turbine-Governor Models	Combined Cycle Plant Steam Turbine Model	UCBGT	Not Accepted*
	General Purpose (Gas Turbine & Single Shaft CC) Turbine-Governor Model	GGOV1	Acceptable
	Brown-Boveri Turbine-Governor Model	BBGOV1	Acceptable
	Cross Compound Turbine-Governor Model	CRCMGV	Acceptable
	Woodward Diesel Governor Model	DEGOV	Acceptable
	Woodward Diesel Governor Model	DEGOV1	Acceptable
	WECC Gas Turbine Governor Model	URGS3T	Not Accepted
	Gas Turbine-Governor Model	GAST	Not Accepted
	Gas Turbine-Governor Model	GAST2A	Not Accepted
	Gas turbine-governor	GASTWD	Not Accepted
	Hydro Turbine-Governor Model	HYGOV	Acceptable
	Hydro Turbine-Governor Model	HYGOV2	Not Recommended
	Hydro Turbine-Governor Lumped Parameter Model	HYGOVM	Acceptable
	Fourth Order Lead-Lag Hydro-Turbine Model	HYGOVR1	Acceptable

* The model is not available in PSS/e Ver 34.9 and newer version.

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Turbine-Governor Models	Hydro Turbine-Governor Traveling Wave Model	HYGOVT	Acceptable
	1981 IEEE Type 1 General Steam Turbine-Governor Model	IEEEG1	Acceptable
	1981 IEEE Type 2 General Approx. Linear Ideal Hydro Model	IEEEG2	Acceptable
	1981 IEEE Type 3 General Mechanical-Hydraulic Model Hydro Turbine-Governor (plants with straightforward penstock config + hydraulic govs of 'dashpot' type)	IEEEG3	Acceptable
	1973 IEEE General Steam Non-Reheat	IEESGO	Acceptable
	IVO Turbine-Governor Model	IVOGO	Acceptable
	Hydro Turbine-Governor Model	PIDGOV	Acceptable
	Pratt & Whitney Turboden Turbine-Governor Model	PWTBD1	Acceptable
	Torsional-Elastic Shaft Model for 25 Masses	SHAF25	Acceptable
	Steam Turbine-Governor Model	TGOV1	Acceptable
	Steam Turbine-Governor Model w/ Fast Valving	TGOV2	Acceptable
	1973 Modified IEEE Type 1 General Steam Turbine-Governor Model w/ Fast Valving	TGOV3	Acceptable
	Modified IEEE Type 1 General Steam Turbine-Governor Model w/ PLU and EVA	TGOV4	Acceptable
	Modified IEEE Type 1 General Steam Turbine-Governor Model w/ Boiler Controls	TGOV5	Acceptable
	Czech Hydro or Steam Turbine-Governor Model	TURCZT	Acceptable
	Tail Water Depression Hydro Governor Model 1	TWDM1T	Acceptable
	Tail Water Depression Hydro Governor Model 2	TWDM2T	Acceptable
	Combined Cycle - Single Shaft Turbine-Governor Model	URCSCT	Acceptable
	Woodward Electronic Hydro Governor Model	WEHGOV	Acceptable
	Westinghouse Digital Governor Model for Gas Turbines	WESGOV	Acceptable
	Woodward PID Hydro Governor Model	WPIDHY	Acceptable
	WECC Double Derivative Hydro Governor Model	WSHYDD	Acceptable
	WECC GP Hydro Turbine-Governor Model	WSHYGP	Acceptable
	Hydro Turbine with American Governor Company controller	H6E	Acceptable
	PID Governor, Double-Derivative Governor, and Turbine (WECC GP governor, WECC G2 turbine-governor)	HYG3	Acceptable
	Modified IEEE Type 1 General Steam Turbine-Governor Model w/ Speed Deadband	WSIEG1	Acceptable
Load Controller Models	Turbine Load Controller Model	LCFB1	Acceptable
Signal Playback Models	Play-In of Voltage and/or Frequency Signal Frequency Playback Model	PLBVF1	Acceptable

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Renewable Energy Resource Models	Generic Type 1 WTG Generator Model (Fixed-speed induction generator)	WT1G1	Acceptable
	Generic Type 2 WTG Generator Model (Variable slip induction generator with variable rotor resistance)	WT2G1	Acceptable
	Generic Type 3 WTG Generator/Converter Model - PSSE (Doubly-fed induction generator)	WT3G1	Not Accepted
	Generic Type 3 WTG Generator/Converter Model - PSLF (Doubly-fed induction generator)	WT3G2	Not Accepted
	Generic Type 4 WTG Generator/Converter Model - PSSE (Variable speed generator with full converter)	WT4G1	Not Accepted
	Generic Type 4 WTG Generator/Converter Model - PSLF (Variable speed generator with full converter)	WT4G2	Not Accepted
	Generic Type 2 WTG Rotor Resistance Control Model	WT2E1	Acceptable
	Generic Type 3 WTG Electrical Control Model	WT3E1	Not Accepted
	Generic Type 4 WTG Electrical Control Model - PSSE	WT4E1	Not Accepted
	Generic Type 4 WTG Electrical Control Model - PSLF	WT4E2	Not Accepted
	Generic Type 1 and 2 Two Mass Turbine Model	WT12T1	Acceptable
	Generic Type 3 WTG Turbine Model	WT3T1	Not Accepted
	Generic Type 3 and 4 WTG Drive Train Model	WTDTA1	Acceptable
	Generic Type 3 WTG Pitch Control Model	WT3P1	Not Accepted
	Generic Type 3 and 4 WTG Pitch Control Model	WTPTA1	Acceptable
	Generic Type 1 and 2 WTG Pitch Control Model	WT12A1	Not Accepted
	Generic Type 2 and 2 WTG Pitch Control Model	WT12A1U_B	Acceptable
	Generic Type 3 and 4 WTG Aerodynamics Model	WTARA1	Acceptable
	Generic Type 3 and 4 WTG Torque Control Model	WTTQA1	Acceptable
	Linearized Model of PV Panel Output Curve	PANELU1	Acceptable
	Linearized Model of PV Panel Solar Irradiance Profile	IRRADU1	Acceptable
	Generic Phase 2 Renewable Energy Generator/Converter Model	REGCA1	Acceptable
	Generic Phase 2 Renewable Energy Electrical Controls Model	REECA1	Acceptable
	Generic Phase 2 Renewable Energy Plant Controller	REPCA1	Acceptable
	Generic Plant Control Model	PLNTBU1	Acceptable
	Generic Phase 2 PV Electrical Controls Model	REECB1	Not Accepted
	Generic Phase 2 Energy Storage Electrical Controls	REECCU1	Acceptable
	Generic Phase 2 Renewable Energy Auxiliary Control Model - Type 3 WTGs	REAX3BU1	Acceptable
	Generic Phase 2 Renewable Energy Auxiliary Control Model - Type 4 WTGs and Solar PV	REAX4BU1	Acceptable
	Generic Phase 2 Renewable Energy Auxiliary Control Model - SVC	SVCAXBU1	Not Accepted*
	Generic Phase 2 Renewable Energy Auxiliary Control Model - FACTS Device	FCTAXBU1	Acceptable
	Generic Phase 2 Renewable Energy Auxiliary Control Model - Synchronous Condenser	SYNAXBU1	Acceptable
	Solar Photovoltaic Generator/Converter Model	PVGU1	Acceptable
	Solar Photovoltaic Electrical Control Model	PVEU1	Acceptable
	Distributed Energy Resource Generator/Converter Model	DERAU1	Acceptable

* The model is not available in PSS/e Ver 34.9 and newer version.

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Load Models	Induction Generator Model with Rotor Flux Transients	CIMTR1	Acceptable
	Induction Motor Model with Rotor Flux Transients	CIMTR2	Acceptable
	Induction Generator Model with Rotor Flux Transients	CIMTR3	Acceptable
	Induction Motor Model with Rotor Flux Transients	CIMTR4	Acceptable
	Induction Motor Model	CIM5BL	Acceptable
	Induction Motor Model	CIM6BL	Acceptable
	Induction Motor Model	CIMWBL	Acceptable
	IEEE Load Model	IEEL__	Acceptable
	Load Frequency Model	LDFR__	Acceptable
	Extended-Term Load Reset Model	EXTLBL	Acceptable
	Complex Load Model	CLOD__	Acceptable
	Composite Load Model	CMLDBLU2	Acceptable
	Composite Load Model w/ DER Component	CMLDBLDGU2	Acceptable
Static Var Systems and FACTS	WECC Generic Continuous Control SVC Model	SVSMO1T2	Acceptable
	WECC Generic Discrete Control SVC Model	SVSMO2T2	Acceptable
	WECC Generic STATCOM-Based SVC Model	SVSMO3T2	Acceptable
	SCR Controlled Static VAR Source Model	CSVGN1	Acceptable
	SCR Controlled Static VAR Source Model	CSVGN3	Acceptable
	SCR Controlled Static VAR Source Model	CSVGN4	Acceptable
	WECC Controlled Static VAR Source Model	CSVGN5	Acceptable
	WECC Controlled Static VAR Source Model	CSVGN6	Acceptable
	Switched Shunt Model	SWSHNT	Acceptable
	American Superconductor DSMES Device	CDSMS1	Acceptable
	Static Condenser FACTS Model	CSTATT	Acceptable
	Static Condenser (modeled as FACTS in power flow)	CSTCNT	Acceptable
	ABB SVC Model	ABBSVC1	Acceptable
	SVC for Switched Shunt	CHSVCT	Acceptable
	SVC for Switched Shunt	CSSCST	Acceptable
	EPRI Superconducting Electromagnetic Energy Storage FACTS Model	CSMEST	Acceptable
	EPRI Battery Energy Storage FACTS Model	CBEST	Acceptable

A-2 PJM Acceptable Model List – continue

Model Type	Model Description	PSS/e Model Name	Status
Protection and Other Models	Under-/Over-Frequency Generator Bus Disconnection Relay	FRQTPAT	Acceptable
	Under-/Over-Frequency Generator Trip Relay	FRQDCAT	Acceptable
	Under-/Over-Voltage Generator Bus Disconnection Relay	VTGTPAT	Acceptable
	Under-/Over-Voltage Generator Trip Relay	VTGDCAT	Acceptable
	Time-Inverse Overcurrent Relay	TIOCR1	Acceptable
	Definite Time Underfrequency Load Shedding Relay	LDS3BL	Acceptable
	Definite Time Undervoltage Load Shedding Relay	LDS3BL	Acceptable
	Out-of-Step Relay with 3 Zones (Lens, Tomato, Circle, Rectangle)	CIROS1	Acceptable
	Out-of-Step Mho Relay with Blinders	SLNOS1	Acceptable
	Switched Capacitor Bank Model	SWCAPT	Acceptable
	IEEE Std 421.5-2016 OEL1B Overexcitation Limiter	OEL1B	Not Accepted*
	IEEE Std 421.5-2016 OEL2C Overexcitation Limiter	OEL2CU1	Acceptable
	IEEE Std 421.5-2016 OEL3C Overexcitation Limiter	OEL3C	Not Accepted*
	IEEE Std 421.5-2016 OEL4C Overexcitation Limiter	OEL4C	Not Accepted*
	IEEE Std 421.5-2016 OEL5C Overexcitation Limiter	OEL5C	Not Accepted*
	IEEE Std 421.5-2016 Overexcitation Limiter	OEL5CU1	Acceptable
	IEEE Std 421.5-2016 UEL1 Underexcitation Limiter	UEL1	Acceptable
	IEEE Std 421.5-2016 UEL2 Underexcitation Limiter	UEL2	Acceptable
	IEEE Std 421.5-2016 UEL2C Underexcitation Limiter	UEL2CU1	Acceptable
	Load Tap Changer Model	OLTC1T	Acceptable
	Variable Frequency Transformer or Rotary Phase Shift Regulator	VFT1	Acceptable

* The model is not available in PSS/e Ver 34.9 and newer version.

A-3 Dynamic Model Example

A-3.1, Example for Conventional Synchronous Generator

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Exciter	Model Status	Type	Turbine Governor	Model Status	Type	Stabilizer	Model Status	Type	Min Exciter	Model Status	Type	Max Exciter	Model Status	Type	Compensator	Model Status	Type	Turbine Load Controller	Model Status	Type
200022	SUSQ 500.0	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
200038	SUSQ 2 24.00	2	1354.00	☑	GENTPJ1	☑	Stnd	AC6A	☑	Stnd	None	☐		PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
208918	SUSQ 1 24.00	1	1354.00	☑	GENTPJ1	☑	Stnd	ESAC3A	☑	Stnd	None	☐		PSS2A	☑	Stnd	None	☐		None	☐		COMP	☑	Stnd	None	☐	
213955	SOUTHWK2 6	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
213957	STHWK3-4 13.	1	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213957	STHWK3-4 13.	2	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213958	STHWK5-6 13.	1	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213958	STHWK5-6 13.	2	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
270803	LASCO STA; R3	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274660	LASCO STA;1U	1	1355.40	☑	GENROU	☑	Stnd	ESDC1A	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274661	LASCO STA;2U	2	1355.00	☑	GENTPJ1	☑	Stnd	AC6A	☑	Stnd	None	☐		PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
272433	SABROOKE ; R1	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274822	ROCKFORD ;11	11	186.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
274823	ROCKFORD ;21	21	198.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
274824	ROCKFORD ;12	12	186.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	

A-3.2, Example for Wind machine – Type III

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
773000	26ARMNA MT 0.6900	W1	111.89	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd
931011	AB1-150 GEN 0.6900	1	62.40	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd
270201	AC2-176 GEN 0.6900	W1	162.76	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd
902355	W2-048 GEN 0.6900	1	205.56	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd

A-3.3, Example for PV Solar Energy and Battery Storage Power Station

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
924154	AB2-059 GEN 0.6000	1	132.30	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	

Model	Model Status	Model Instance	Type
VTGTPAT	☑	92415401	Stnd
VTGTPAT	☑	92415402	Stnd
VTGTPAT	☑	92415403	Stnd
VTGTPAT	☑	92415404	Stnd
VTGTPAT	☑	92415405	Stnd
VTGTPAT	☑	92415406	Stnd
FRQTPAT	☑	92415407	Stnd
FRQTPAT	☑	92415408	Stnd
FRQTPAT	☑	92415409	Stnd
FRQTPAT	☑	92415410	Stnd

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
105	SMA 0.5500	1	87.50	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
107	TM1833_GEN 0.4000	1	24.00	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
108	TMININ_4.2 0.6300	1	12.60	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
109	TM1NIN_3.36 0.6300	1	13.44	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	

Model	Model Status	Model Instance	Type
VTGTPAT	☑	10501	Stnd
VTGTPAT	☑	10502	Stnd
VTGTPAT	☑	10503	Stnd
VTGTPAT	☑	10504	Stnd
VTGTPAT	☑	10505	Stnd
VTGTPAT	☑	10506	Stnd
VTGTPAT	☑	10507	Stnd
VTGTPAT	☑	10508	Stnd
FRQTPAT	☑	10509	Stnd
FRQTPAT	☑	10510	Stnd
FRQTPAT	☑	10511	Stnd
FRQTPAT	☑	10512	Stnd
FRQTPAT	☑	10513	Stnd
FRQTPAT	☑	10514	Stnd
VTGTPAT	☑	10701	Stnd
VTGTPAT	☑	10702	Stnd
VTGTPAT	☑	10703	Stnd
VTGTPAT	☑	10704	Stnd
VTGTPAT	☑	10705	Stnd
VTGTPAT	☑	10706	Stnd
VTGTPAT	☑	10707	Stnd
VTGTPAT	☑	10708	Stnd
FRQTPAT	☑	10709	Stnd
FRQTPAT	☑	10710	Stnd
FRQTPAT	☑	10711	Stnd
FRQTPAT	☑	10712	Stnd
FRQTPAT	☑	10713	Stnd
FRQTPAT	☑	10714	Stnd
VTGTPAT	☑	10801	Stnd
VTGTPAT	☑	10802	Stnd
VTGTPAT	☑	10803	Stnd
VTGTPAT	☑	10804	Stnd
VTGTPAT	☑	10805	Stnd
VTGTPAT	☑	10806	Stnd
VTGTPAT	☑	10807	Stnd
VTGTPAT	☑	10808	Stnd
FRQTPAT	☑	10809	Stnd
FRQTPAT	☑	10810	Stnd
FRQTPAT	☑	10811	Stnd
FRQTPAT	☑	10812	Stnd
FRQTPAT	☑	10813	Stnd
FRQTPAT	☑	10814	Stnd
VTGTPAT	☑	10901	Stnd
VTGTPAT	☑	10902	Stnd
VTGTPAT	☑	10903	Stnd
VTGTPAT	☑	10904	Stnd
VTGTPAT	☑	10905	Stnd
VTGTPAT	☑	10906	Stnd
VTGTPAT	☑	10907	Stnd
VTGTPAT	☑	10908	Stnd
FRQTPAT	☑	10909	Stnd
FRQTPAT	☑	10910	Stnd
FRQTPAT	☑	10911	Stnd
FRQTPAT	☑	10912	Stnd
FRQTPAT	☑	10913	Stnd
FRQTPAT	☑	10914	Stnd

A-4, Momentary Cessation requirement to inverter based

1. GOs should contact their inverter manufacturer(s) to understand whether the specific makes and models of their inverters, as configured at each specific generating facility, use momentary cessation.

2. GOs should obtain the following information from the inverter manufacturer(s) for any inverters that use momentary cessation:

a) Momentary Cessation Low Voltage Threshold or Curve: The low voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.

b) Momentary Cessation High Voltage Threshold or Curve: The high voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.

c) Recovery Delay: The time following restoration of terminal voltage to above the momentary cessation low voltage threshold within acceptable levels[7] before the inverter begins injecting current once again.

d) Active Current Recovery Ramp Rate: The ramp rate (expressed in terms of percent of rated current per second) of recovery in active current injection following momentary cessation.

e) Reactive Current Recovery Limits: Any limits imposed on the reactive current should be described. This may be a ramp rate limit, a reduced current limit for a specified period of time, or no limit imposed. Most inverters may not have these limits on reactive current injection, but this should be verified with the manufacturer.

A-5, Acquire Dynamic Model

A-5.1 NERC MOD-026-R2

R2. Each Generator Owner shall provide for each applicable unit, a verified generator excitation control system or plant volt/var control function model, including documentation and data (as specified in Part 2.1) to its Transmission Planner in accordance with the periodicity specified in MOD-026 Attachment 1. *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

2.1. Each applicable unit's model shall be verified by the Generator Owner using one or more models acceptable to the Transmission Planner. Verification for individual units less than 20 MVA (gross nameplate rating) in a generating plant (per Section 4.2.1.2, 4.2.2.2, or 4.2.3.2) may be performed using either individual unit or aggregate unit model(s), or both. Each verification shall include the following:

2.1.1. Documentation demonstrating the applicable unit's model response matches the recorded response for a voltage excursion from either a staged test or a measured system disturbance,

2.1.2. Manufacturer, model number (if available), and type of the excitation control system including, but not limited to static, AC brushless, DC rotating, and/or the plant volt/var control function (if installed),

2.1.3. Model structure and data including, but not limited to reactance, time constants, saturation factors, total rotational inertia, or equivalent data for the generator,

2.1.4. Model structure and data for the excitation control system, including the closed loop voltage regulator if a closed loop voltage regulator is installed or the model structure and data for the plant volt/var control function system,

2.1.5. Compensation settings (such as droop, line drop, differential compensation), if used, and

2.1.6. Model structure and data for power system stabilizer, if so equipped.

Figure 6 MOD-026 Requirement 2

A-5.2 NERC MOD-027-R2

R2. Each Generator Owner shall provide, for each applicable unit, a verified turbine/governor and load control or active power/frequency control model, including documentation and data (as specified in Part 2.1) to its Transmission Planner in accordance with the periodicity specified in MOD-027 Attachment 1. *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

2.1. Each applicable unit's model shall be verified by the Generator Owner using one or more models acceptable to the Transmission Planner. Verification for individual units rated less than 20 MVA (gross nameplate rating) in a generating plant (per Section 4.2.1.2, 4.2.2.2, or 4.2.3.2) may be performed using either individual unit or aggregate unit model(s) or both. Each verification shall include the following:

2.1.1. Documentation comparing the applicable unit's MW model response to the recorded MW response for either:

- A frequency excursion from a system disturbance that meets MOD-027 Attachment 1 Note 1 with the applicable unit on-line,
- A speed governor reference change with the applicable unit on-line, or
- A partial load rejection test,[2]

2.1.2. Type of governor and load control or active power control/frequency control[3] equipment,

2.1.3. A description of the turbine (e.g. for hydro turbine - Kaplan, Francis, or Pelton; for steam turbine - boiler type, normal fuel type, and turbine type; for gas turbine - the type and manufacturer; for variable energy plant - type and manufacturer),

2.1.4. Model structure and data for turbine/governor and load control or active power/frequency control, and

2.1.5. Representation of the real power response effects of outer loop controls (such as operator set point controls, and load control but excluding AGC control) that would override the governor response (including blocked or nonfunctioning governors or modes of operation that limit Frequency Response), if applicable.

Figure 7 MOD-027 Requirement 2

A-5.3 Industrial Stands and technical documents

Conventional Generator

1. *IEEE 421.1 Definitions for Excitation Systems for Synchronous Machines*
2. *IEEE 421.2 Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems*
3. *IEEE 421.5 IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*
4. *IEEE Task Force on Generator Model Validation Testing of the Power System Stability Subcommittee, "Guidelines for Generator Stability Model Validation Testing," IEEE PES General Meeting 2007, paper 07GM1307*
5. *L. Pereira "New Thermal Governor Model Development: Its Impact on Operation and Planning Studies on the Western Interconnection" IEEE POWER AND ENERGY MAGAZINE, MAY/JUNE 2005*
6. *D.M. Cabbell, S. Rueckert, B.A. Tuck, and M.C. Willis, "The New Thermal Governor Model Used in Operating and Planning Studies in WECC," in Proc. IEEE PES General Meeting, Denver, CO, 2004*
7. *S. Patterson, "Importance of Hydro Generation Response Resulting from the New Thermal Modeling-and Required Hydro Modeling Improvements," in Proc. IEEE PES General Meeting, Denver, CO, 2004*

PV Gednerator and BESS

8. *NERC. Modeling Notification Recommended Practices for Modeling Momentary Cessation Initial Distribution: February 2018*
9. *K. Clark, R.A. Walling, N.W. Miller, "Solar Photovoltaic (PV) Plant Models in PSLF," IEEE/PES General Meeting, Detroit, MI, July 2011*
10. *K. Clark, N.W. Miller, R.A. Walling, "Modeling of GE Solar Photovoltaic (PV) Plants for Grid Studies," version 1.1, April 2010*

Wind Plant

11. *M. Asmine, J. Brochu, J. Fortmann, R. Gagnon, Y. Kazachkov, C.-E. Langlois, C. Larose, E. Muljadi, J. MacDowell, P. Pourbeik, S. A. Seman, and K. Wiens, "Model Validation for Wind Turbine Generator Models", IEEE Transactions on Power System, Volume 26, Issue 3, August 2011*
12. *A. Ellis, E. Muljadi, J. Sanchez-Gasca, Y. Kazachkov, "Generic Models for Simulation of Wind Power Plants in Bulk System Planning Studies," IEEE PES General Meeting 2011, Detroit, MI, July 24-28*
13. *N.W. Miller, J. J. Sanchez-Gasca, K. Clark, J.M. MacDowell, "Dynamic Modeling of GE Wind Plants for Stability Simulations," IEEE PES General Meeting 2011, Detroit, MI, July 24-28*
14. *A. Ellis, Y. Kazachkov, E. Muljadi, P. Pourbeik, J.J. Sanchez-Gasca, Working Group Joint Report – WECC Working Group on Dynamic Performance of Wind Power Generation & IEEE Working Group on Dynamic Performance of Wind Power Generation, "Description and Technical Specifications for Generic WTG Models – A Status Report," Proc. IEEE PES 2011 Power Systems Conference and Exposition (PSCE), March 2011, Phoenix, AZ*
15. *K. Clark, N.W. Miller, J. J. Sanchez-Gasca, "Modeling of GE Wind Turbine Generators for Grid Studies," version 4.5, April 16, 2010, Available from GE Energy*
16. *R.J. Piwko, N.W. Miller, J.M. MacDowell, "Field Testing & Model Validation of Wind Plants," in Proc. IEEE PES General Meeting, Pittsburg, PA, July 2008*
17. *W.W. Price and J. J. Sanchez-Gasca, "Simplified Wind Turbine Generator Aerodynamic Models for Transient Stability Studies," in PROC IEEE PES 2006 Power Systems Conf. Expo. (PSCE), Atlanta, GA, October 1, 2006, p. 986-992*
18. *J.J. Sanchez-Gasca, R.J. Piwko, N. W. Miller, W. W. Price, "On the Integration of Wind Power Plants in Large Power Systems," Proc. X Symposium of Specialists in Electric and Expansion Planning (SEPOPE), Florianopolis, Brazil, May 2006*

Misc

19. *P. Pourbeik, C. Pink and R. Bisbee, "Power Plant Model Validation for Achieving Reliability Standard Requirements Based on Recorded On-Line Disturbance Data", Proceedings of the IEEE PSCE, March, 2011*

A-6, System Model

A-6.1, Power flow case model

The system power flow model can be formatted in*.raw, *.sav, and described as the Single Machine Infinite Bus System. Some examples are shown below.

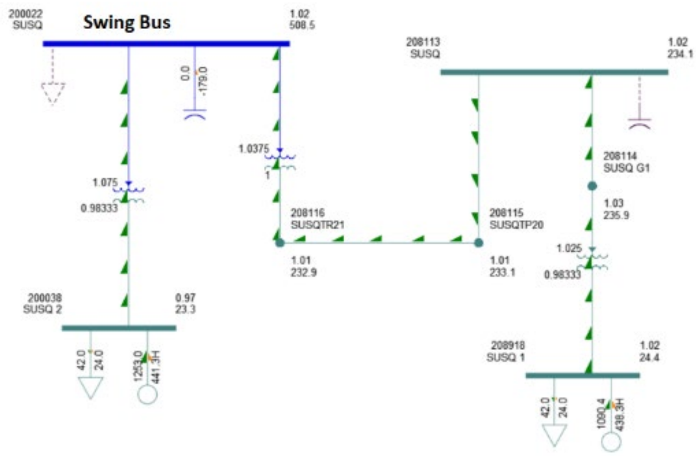

Figure 8   Example of SMIB system model from one conventional power plant

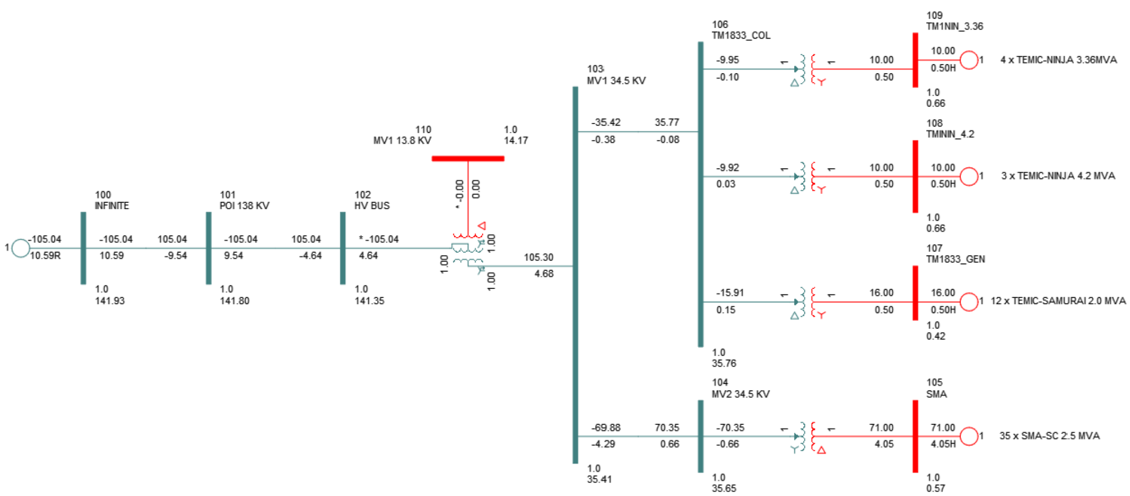

Figure 9   Example of SMIB system model from one renewable (aggregated) power plant

A-6.2, Dynamic Model Format

The dynamic model shall be either in the table or dyr formatted in PSS/e Ver.34, or both. Some examples are shown below.

```
243188 'GENROE' 1     6.1500      0.42000E-01  0.68000      0.61000E-01
         3.1400      0.0000      2.3970       2.3640      0.41500
        0.59400     0.33300     0.24200      0.16200      0.63000      /
243188 'IEEEVC' 1     0.0000     -0.30000E-01  /
243188 'ESST1A' 1          1            1       0.0085       99.000
        -99.000      1.0000      5.6250      0.10000      0.10000
         405.00     0.0000   5.9400      -5.3300       5.9400
        -5.3300     0.57000E-01   0.0000       1.0000       0.0000
         5.6800    /
243188 'IEEEG1' 1          0           0       16.800       0.0000
         0.0000     0.30000     0.10000     -0.10000      1.0000
         0.0000     0.21000     0.21000      0.0000       11.800
        0.19000      0.0000      6.4000      0.60000       0.0000
         0.0000      0.0000      0.0000    /
```

Figure 10 Example of dynamic dyr file from one conventional power plant

```
105   'REGCA1'   1
         0
      0.0200       10.000      0.9000      0.50000     1.0000
      1.2000       0.001       0.00000    -1.0         0.0000
      0.0000       20.000     -20.0000     0.7000 /
105   'REECA1' 1
      0    0    1    0    0    0
      0.9000       1.1000       0.010      -0.100          0.1000
      2.0000       2.0         -2.0         0.0000          1.0
      0.0          0.0          0.05        0.6            -0.4
      1.200        0.800        0.0         1.0             0.0
      1.0          0.0          0.46        1.0            -1.0
      1.0          0.0          1.0         0.01            0.0
      1.0          0.33         1.0         0.66            1.0
      1.0          1.0          0.0         1.0             0.33
      1.0          0.66         1.0         1.0             1.0 /
105 'USRMDL' 1 'REPCAU1' 107 0 7 27 7 9
      101    102    101    '1'    0    1    0
      0.04         0.05        0.35        0.0          0.04
      0.88         0.0019      0.007       0.053         999.0
     -999.0        0.00        0.00        0.60         -0.80
      0.0          0.50        0.04        0.000        0.000
      999         -999         1.0         0.0          0.04
      0.04         0.04 /

 10501   'VTGTPAT'     105    105  '1'  -1.0000      1.2000      0.0010      0.0000      /
 10502   'VTGTPAT'     105    105  '1'  -1.0000      1.1500      0.2000      0.0000      /
 10503   'VTGTPAT'     105    105  '1'  -1.0000      1.1300      0.5000      0.0000      /
 10504   'VTGTPAT'     105    105  '1'  -1.0000      1.1000      1.0000      0.0000      /
 10505   'VTGTPAT'     105    105  '1'   0.4300      5.0000      0.1500      0.0000      /
 10506   'VTGTPAT'     105    105  '1'   0.6200      5.0000      0.3000      0.0000      /
 10507   'VTGTPAT'     105    105  '1'   0.7200      5.0000      2.0000      0.0000      /
 10508   'VTGTPAT'     105    105  '1'   0.8700      5.0000      3.0000      0.0000      /
 10509   'FRQTPAT'     105    105  '1'  -100.00      61.400      30.000      0.0000      /
 10510   'FRQTPAT'     105    105  '1'  -100.00      61.750      10.000      0.0000      /
 10511   'FRQTPAT'     105    105  '1'  -100.00      62.000      0.0010      0.0000      /
 10512   'FRQTPAT'     105    105  '1'   58.450      100.00      30.000      0.0000      /
 10513   'FRQTPAT'     105    105  '1'   58.200      100.00      10.000      0.0000      /
 10514   'FRQTPAT'     105    105  '1'   57.600      100.00      0.0010      0.0000      /
```

Figure 11   Example of dynamic dyr file from one renewable (aggregated) power plant

Table 1: Parameters for the *REGCA1* model, on the WTG base. The MVA based of the aggregated WTG models is given in Appendix A, Figure A-5.

ICON	WTG 1	WTG 2	Explanation
M	0	0	OEM Data (*Lvplsw*)
CONs			**Explanation**
J	0.02	0.02	OEM Data (*Tg*)
J+1	1.1	1.1	OEM Data (*rrpwr*)
J+2	0.9	0.9	OEM Data (*Brkpt*)
J+3	0.4	0.4	OEM Data (*Zerox*)
J+4	1.2	1.2	OEM Data (*Lvpl1*)
J+5	1.1	1.1	OEM Data (*Volim*)
J+6	0.001	0.001	OEM Data (*Lvpnt1*)
J+7	0.0	0.0	OEM Data (*Lvpnt0*)
J+8	-1.3	-1.3	OEM Data (*Iolim*)
J+9	0.02	0.02	OEM Data (*Tfltr*)
J+10	0.7	0.7	OEM Data (*Khv*)
J+11	99	99	Disable per OEM Data (*Iqrmax*)
J+12	-99	-99	Disable per OEM Data (*Iqrmin*)
J+13	1.0	1.0	Accel, acceleration factor (0 < Accel <= 1)

Table 2: Parameters for the *REECA1* model, on the WTG base. The MVA based of the aggregated WTG models is given in Appendix A, Figure A-5.

ICONs	WTG 1	WTG 2	Explanation
M	0	0	This module must control its own terminal voltage
M+1	0	0	OEM Data (*PFFLAG*)
M+2	1	1	OEM Data (*VFLAG*)
M+3	0	0	OEM Data (*QFLAG*)
M+4	0	0	OEM Data (*PFLAG*)
M+5	0	0	OEM Data (*PQFLAG*)
CONs			**Explanation**
J	0.85	0.85	Disable (*Vdip*)
J+1	1.1	1.1	Disable (*Vup*)
J+2	0.02	0.02	Verified by test (*Trv*)
J+3	-0.1	-0.1	Disable (*dbd1*)
J+4	0.1	0.1	Disable (*dbd2*)
J+5	2.11	2.11	Disable (*Kqv*)
J+6	1.0	1.0	Disable (*Iqh1*)
J+7	-1.0	-1.0	Disable (*Iql1*)
J+8	1	1	Irrelevant since *Vdip* disabled (*Vref0*)
J+9	0	0	Disable (*Iqfrz*)
J+10	0	0	Disable (*Thld*)
J+11	0	0	Disable (Thld2)
J+12	0.05	0.05	OEM Data (*Tp*)
J+13	0.4675	0.4675	OEM Data (*QMax*) – confirmed limit
J+14	-0.425	-0.425	OEM Data (*QMin*) – confirmed limit

Figure 12 Example of tabular dynamic model file from one renewable (aggregated) power plant

Excitation Model IEEE 421.5 Std. ST1A
PSS/E Model ESST1A

Description	Parameter	Value	Units	ICON
UEL connection code (1, 2 or 3)	UEL	1		M
PSS connection code (1 or 2)	VOS	1		M+1
Description	**Parameter**	**Value**	**Units**	**CON**
voltage transducer time constant	Tr	0	s	J
maximum voltage error	Vimax	99	pu	J+1
minimum voltage error	Vimin	-99	pu	J+2
1st lead-lag numerator time constant	Tc	1	s	J+3
1st lead-lag denominator time constant	Tb	5.625	s	J+4
2nd lead-lag numerator time constant	Tc1	0.1	s	J+5
2nd lead-lag denominator time constant	Tb1	0.1	s	J+6
AVR gain	Ka	405	pu	J+7
rectifier bridge time constant	Ta	0.01	s	J+8
maximum voltage regulator output	Vamax	5.94	pu	J+9
minimum excitation voltage	Vamin	-5.33	pu	J+10
maximum excitation voltage	Vrmax	5.94	pu	J+11
minimum excitation voltage	Vrmin	-5.33	pu	J+12
rectifier regulation factor	Kc	0.057	pu	J+13
rate feedback gain	Kf	0	pu	J+14
rate feedback time constant	Tf (>0)	1	s	J+15
field current limiter gain	Klr	0	pu	J+16
field current limit	Ilr	5.68	pu	J+17

Notes:

1) The PSS/E program requires the smallest time constant to be greater than 2 times the integration time step. For TR, TA < (2 x integration step), set TA=0 and TR=smallest allowable value. Kestrel suggests using 0.017 seconds as the smallest allowable value if the integration time step is 1/2 cycle (PSS/E default). A value of 0.0085 seconds can be used as the smallest allowable value if the integration time step is 1/4 cycle (common value in many regions in North America).

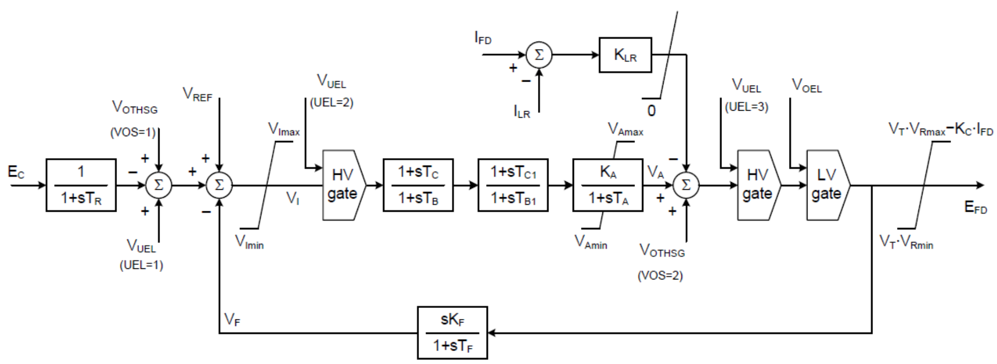

Figure 13 Example of tabular dynamic model file from one conventional power plant

A-7, NERC MOD-026/027 Requirement 3

A-7.1, NERC MOD-026 R-3

R3. Each Generator Owner shall provide a written response to its Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit:

- Written notification from its Transmission Planner (in accordance with Requirement R6) that the excitation control system or plant volt/var control function model is not usable,
- Written comments from its Transmission Planner identifying technical concerns with the verification documentation related to the excitation control system or plant volt/var control function model, or
- Written comments and supporting evidence from its Transmission Planner indicating that the simulated excitation control system or plant volt/var control function model response did not match the recorded response to a transmission system event.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification[3] (in accordance with Requirement R2). *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

Figure 14 MOD-026 Requirement 3

A-7.2, NERC MOD-027 R-3

R3. Each Generator Owner shall provide a written response to its Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit.

- Written notification, from its Transmission Planner (in accordance with Requirement R5) that the turbine/governor and load control or active power/frequency control model is not "usable,"
- Written comments from its Transmission Planner identifying technical concerns with the verification documentation related to the turbine/governor and load control or active power/frequency control model, or
- Written comments and supporting evidence from its Transmission Planner indicating that the simulated turbine/governor and load control or active power/frequency control response did not approximate the recorded response for three or more transmission system events.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification[4] (in accordance with Requirement R2). *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

Figure 15 MOD-027 Requirement 3

Development History

Revision: 0	Date: 05/02/2022
Author:	Dengjun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	Tao He Senior Engineer, System Planning Modeling and Support
Approver:	David Egan Manager, System Planning Modeling and Support
Reason for Review	Initial Version

Revision: 1	Date: 07/28/2022
Author:	Dengjun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	Tao He Senior Engineer, System Planning Modeling and Support
Approver:	David Egan Manager, System Planning Modeling and Support
Reason for Review	Edit and arrangement for improved user experience

Revision: 2	Date: 10/18/2023
Author:	Dengjun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	Tao He Lead Engineer, System Planning Modeling and Support
Approver:	David Egan Sr. Manager, System Planning Modeling and Support
Reason for Review	2023 annual review

Revision: 3	Date: 03/22/2024
Author:	Dengjun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	Tao He Lead Engineer, System Planning Modeling and Support
Approver:	David Egan Sr. Manager, System Planning Modeling and Support
Reason for Review	2024 annual review and rearrange location of user guide and interface section to improve user experience.